Geographic and temporal distribution of *Agriotes obscurus* and *A. lineatus* (Coleoptera: Elateridae) in British Columbia and Washington as determined by pheromone trap surveys

BOB VERNON

AGRICULTURE AND AGRI-FOOD CANADA, PACIFIC AGRI-FOOD RESEARCH CENTRE, AGASSIZ, BC, CANADA V0M 1A0

ERIC LAGASA

WASHINGTON STATE DEPARTMENT OF AGRICULTURE, OLYMPIA, WA, UNITED STATES 98504-2560

HUGH PHILIP

BC MINISTRY OF AGRICULTURE, FOOD & FISHERIES, KELOWNA, BC, CANADA V1X 7G5

ABSTRACT

Initial and peak catch of male Agriotes obscurus (L.) in pheromone traps in the lower Fraser Valley of BC occurred 15.6 and 18.7 days, respectively, before A. lineatus (L.). Both A. obscurus and A. lineatus were taken in pheromone traps from each of 77 fields monitored throughout the lower Fraser Valley during 2000 and 2001, expanding the known ranges of both species. No specimens of either species were taken in pheromone traps set at 56 sites distributed throughout the Okanagan, Similkameen and Nichola Valleys in 2000, but one specimen of A. lineatus was found in a private collection that had been captured near Merritt BC. This is the first record of A. lineatus in BC outside of the lower Fraser Valley. Of nine counties surveyed in Washington State in 2000, A. obscurus was taken in traps at several sites in Whatcom county, especially along the Canada/US border, and A. lineatus was taken at several sites in Whatcom, Snohomish and Pierce counties.

Key words: wireworms, Elateridae, *Agriotes lineatus*, *Agriotes obscurus*, pheromone traps

INTRODUCTION

In 1952, a proceedings of the Entomological Society of British Columbia was published to commemorate the fiftieth anniversary of the society. In that issue, an article entitled, 'List of the Elateridae of British Columbia', was published by M.C. Lane, an entomologist from the Bureau of Entomology and Plant Quarantine in Walla Walla, Washington. Among the 150 species known to be in BC at that time, Lane listed the dusky click beetle, *Agriotes obscurus* (L.) (Coleoptera: Elateridae), and the lined click beetle, *A. lineatus* (L.), as being present on Vancouver Island but not on the mainland (Lane 1952). These species had just been discovered in 1949 by King (1950) at Cobble Hill, near Victoria, and shortly thereafter, *A. obscurus* was found on the mainland at the eastern end of the lower Fraser Valley near Agassiz (King *et al.* 1952). By 1980, *A. obscurus* larvae and related damage had been reported from several farms in Surrey, about 70 km west of Agassiz, and *A. lineatus* had spread from Vancouver Island to Vancouver on the mainland (Wilkinson 1980). In a recent survey conducted in the lower Fraser Valley in 1996 and 1997, *A. obscurus* was taken in pitfall traps

from several locations between Delta and Agassiz (Vernon and Päts 1997). The easternmost record of *A. obscurus* was in Laidlaw, between Hope and Agassiz. The survey also showed that *A. lineatus* was now established in Delta, which was the only region where the two species overlapped in pitfall traps in the lower Fraser Valley. A single specimen of *A. obscurus* caught in a pitfall trap in a field of raspberries in Lynden, WA in 1997 was the first recorded occurrence of this species in Washington State (Vernon and Päts 1997). Other than the Lynden capture, neither species has been reported outside of the lower Fraser Valley in BC, or elsewhere in Washington.

The initial discoveries of *A. obscurus* and *A. lineatus* in BC (King 1950; King *et al.* 1952) were of particular importance at that time, since both were introductions from Europe, and both were considered among Europe's most destructive insects (Eidt 1953). It is believed that both species were introduced to BC from Europe around 1900 (Wilkinson 1963), although the actual time and means of introduction are not known for certain. It has been hypothesized that *A. obscurus* larvae may have been introduced to the Agassiz area on hops with soil brought from Europe (A.T.S. Wilkinson, personal communication). Introductions of *A. obscurus*, *A. lineatus* and *A. sputator* (L.) to the east coast of Canada in the 1800s have been attributed to the dumping of soil ballast from ships coming from Europe (Eidt 1953). Instances of ballast dumping are also recorded in areas of Puget Sound and Portland Oregon in the US (Lindroth 1957), and in Departure Bay just north of Nanaimo on Vancouver Island (Scudder 1958).

Once established in Canada, the dispersal of *A. obscurus* and *A. lineatus* was believed to have been slow due to the 4-year life cycle of these species (Wilkinson *et al.* 1976). Following its discovery in Agassiz, BC in 1952 (King *et al.* 1952), a subsequent delimitation survey showed that the area affected was confined to less than 320 ha, which was bounded by the Fraser River on the south and east and by heavily wooded terrain on the west and north. (Wilkinson 1957). In Nova Scotia, introduced *Agriotes* spp. were initially restricted to the vicinity of old ports that were also confined by water and forests (Eidt 1953). It was also believed by workers studying these species in Nova Scotia and BC that dispersal was slow because the adults had not been observed to fly (Wilkinson *et al.* 1976; Eidt 1953). With the gradual urbanization of BC and Nova Scotia, however, several new manmade avenues of dispersal appear to be accelerating the movement of wireworms into new areas. The movement of wireworm-infested soil for example, either as topsoil for landscaping purposes, or in soil associated with sod farms or ornamental plants has likely played a role in spreading both species throughout the lower Fraser Valley of BC and beyond since the early reports (R.S. Vernon, personal observation).

When organochlorine insecticides commonly used to control wireworms were withdrawn from BC and elsewhere, Wilkinson (1980) predicted that European wireworms would eventually become a serious threat to agriculture in BC. This prediction has come true, particularly within the past decade where wireworm damage has increased dramatically in small fruit, vegetable, ornamental and forage crops throughout the Fraser Valley. Wireworms have been particularly damaging to potatoes in the lower Fraser Valley, where holes and scars have reduced marketable yields on conventional farms, and where entire fields of organic potatoes have been rendered unmarketable (R. S. Vernon, personal observation). Wireworms are also a major concern to the strawberry industry, where considerable seedling mortality can occur to newly established plantings, and where wireworms in mature plantings will enter fruit in contact with the ground to become contaminants during processing. The damage is always associated with *A. obscurus* or *A. lineatus* or both (Vernon and Päts 1997), but because these species are extremely difficult to distinguish from each other using larval characteristics alone (Wilkinson 1963), it is not known what species are damaging crops in certain areas.

The recent survey of *A. obscurus* and *A. lineatus* distribution in the lower Fraser Valley and Lynden Washington by Vernon and Päts (1997), relied primarily upon historical Elaterid

collections at the Pacific Agri-Food Research Centre (AAFC) at Agassiz, and pitfall traps placed in a total of 12 field sites during 1996 and 1997. In 1999, pheromone traps for *A. obscurus* and *A. lineatus* were developed that are much more convenient and effective at trapping adult male click beetles than pitfall traps (R. S. Vernon, unpublished data). In 2000, these pheromone traps were used to survey the Okanagan, Similkameen and Nichola Valleys of BC and western Washington for *A. obscurus* and *A. lineatus*. The traps were also used in strawberry and potato fields throughout the lower Fraser Valley during 2000 and 2001, and the spatial and temporal occurrence of *A. obscurus* and *A. lineatus* beetles in these three survey areas is described in this paper.

MATERIALS AND METHODS

Pheromone trapping. The traps used in these surveys were Vernon Beetle Traps (PheroTech Inc., Delta, BC) baited with bubble cap lures containing pheromone blends for *A. lineatus* and *A. obscurus* (LaGasa *et al.* 2000). The pheromone lure formulations remain proprietary information at the present time. The trap, constructed of durable polyvinyl chloride (PVC), is designed to capture and confine adult male beetles that are attracted to the internal pheromone lure and fall in after ascending shallow ramps. No killing agent or preservative was used inside the traps, which relied on regular servicing to provide specimens in good condition. Traps were placed at ground level, with entry ramps flush with or slightly covered by adjacent soil to provide unimpeded beetle entry. Sample collection involved removal of one of the ramp inserts and shaking the trap contents into a tray.

Lower Fraser Valley surveys. In the spring of 2000, pheromone traps for *A. obscurus* and *A. lineatus* were installed in 17 strawberry fields in the lower Fraser Valley from Delta to Chilliwack (Fig. 1). Trap placement, spacing and numbers were dependent on field size and shape, but generally 10 traps were installed along each of six evenly spaced rows of strawberries to achieve good field coverage. Traps were consecutively numbered (e.g. 1 to 60) with odd- numbered traps baited with *A. lineatus* lures and even-numbered traps with *A. obscurus* lures. This was done for both species throughout the growing season in the westernmost seven fields (Richmond, Delta and Surrey), whereas in the easternmost 10 fields (Aldergrove, Abbotsford and Chilliwack), *A. lineatus* traps were not installed until late May. Traps were checked on a weekly to biweekly basis from mid-April to mid-July, during which time all beetles were removed and saved for identification.

Additional pheromone traps purchased by growers were installed by private consultants in headland areas surrounding 18 potato fields in Delta in 2000. Each field had a single pair of *A. obscurus* and *A. lineatus* traps, with 10 m between the paired traps. These traps were checked weekly from 13 April to 3 July, during which time all beetles were removed and saved for identification.

In the Spring of 2001, pheromone traps for *A. obscurus* and *A. lineatus* were installed in 50 strawberry fields in the lower Fraser Valley, again from Delta to Chilliwack but also in areas north of the Fraser River that had never been surveyed (Fig. 1). Seven of the fields monitored in 2001 had also been monitored with pheromone traps during the 2000 growing season. Each field had five pairs of *A. obscurus* and *A. lineatus* traps. Trap pairs were located midway along each side of each field, about 10 m in from the field edges with about 10 m between paired traps. Another pair of traps was located in the approximate center of each field. Traps were checked on a biweekly basis from mid-March to mid-July, during which time all beetles were removed and saved for identification. A 10-ha field of pasture in Surrey, and a 1-ha fallowed field in Agassiz were also monitored in 2001 for *A. obscurus* and *A. lineatus* using the pheromone traps, with four of each trap placed at random locations inside the fields.

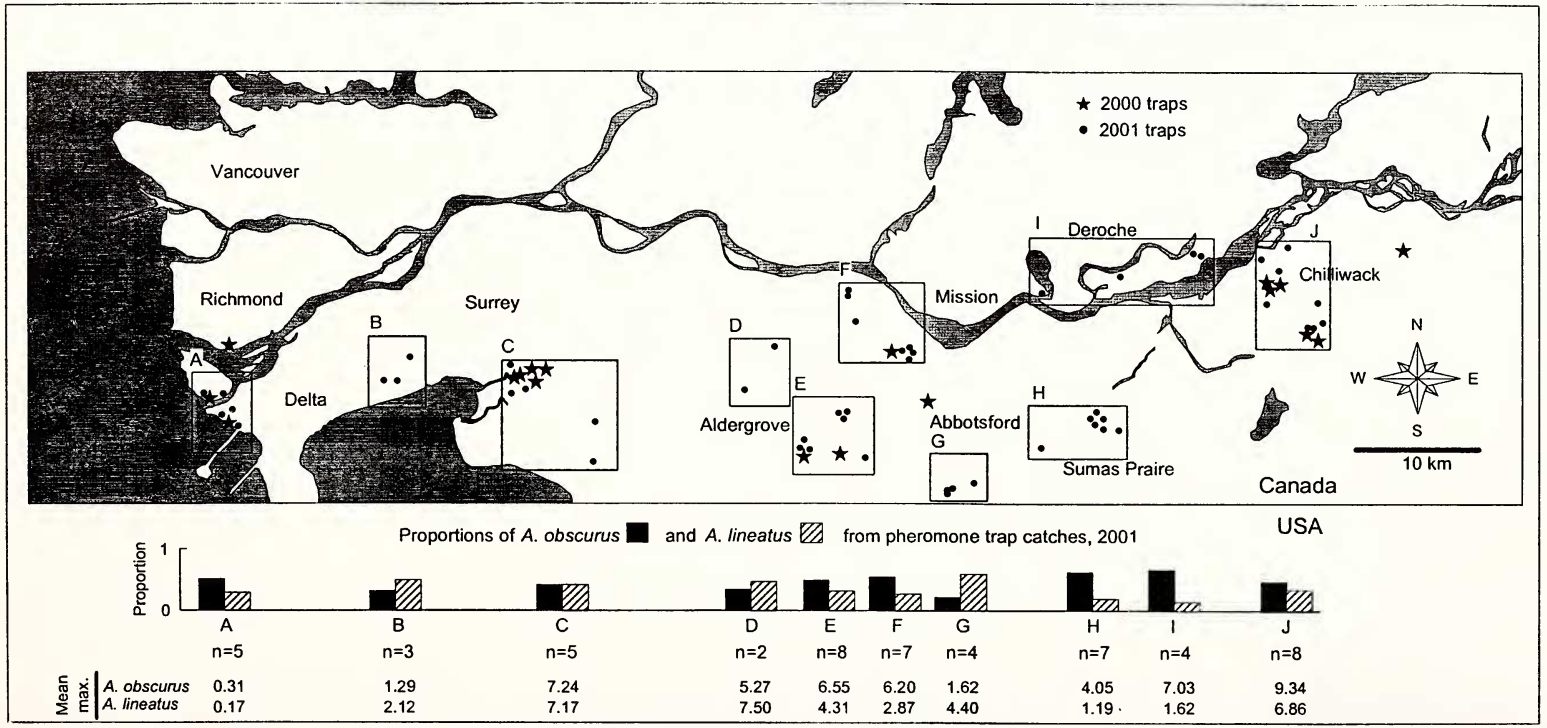

Figure 1. Locations of pheromone traps for both *A. obscurus* and *A. lineatus* in agricultural regions of the lower Fraser Valley in 2000 and 2001. Histograms represent the mean proportion of *A. obscurus* versus *A. lineatus* taken among fields in discrete areas of the Fraser Valley in 2001 (proportions were calculated using the grande mean peak catches of each species in each area, shown under each histogram, between March and July, 2001; n = number of fields). Mean maximum *A. obscurus* and *A. lineatus* cited are beetles per trap per day.

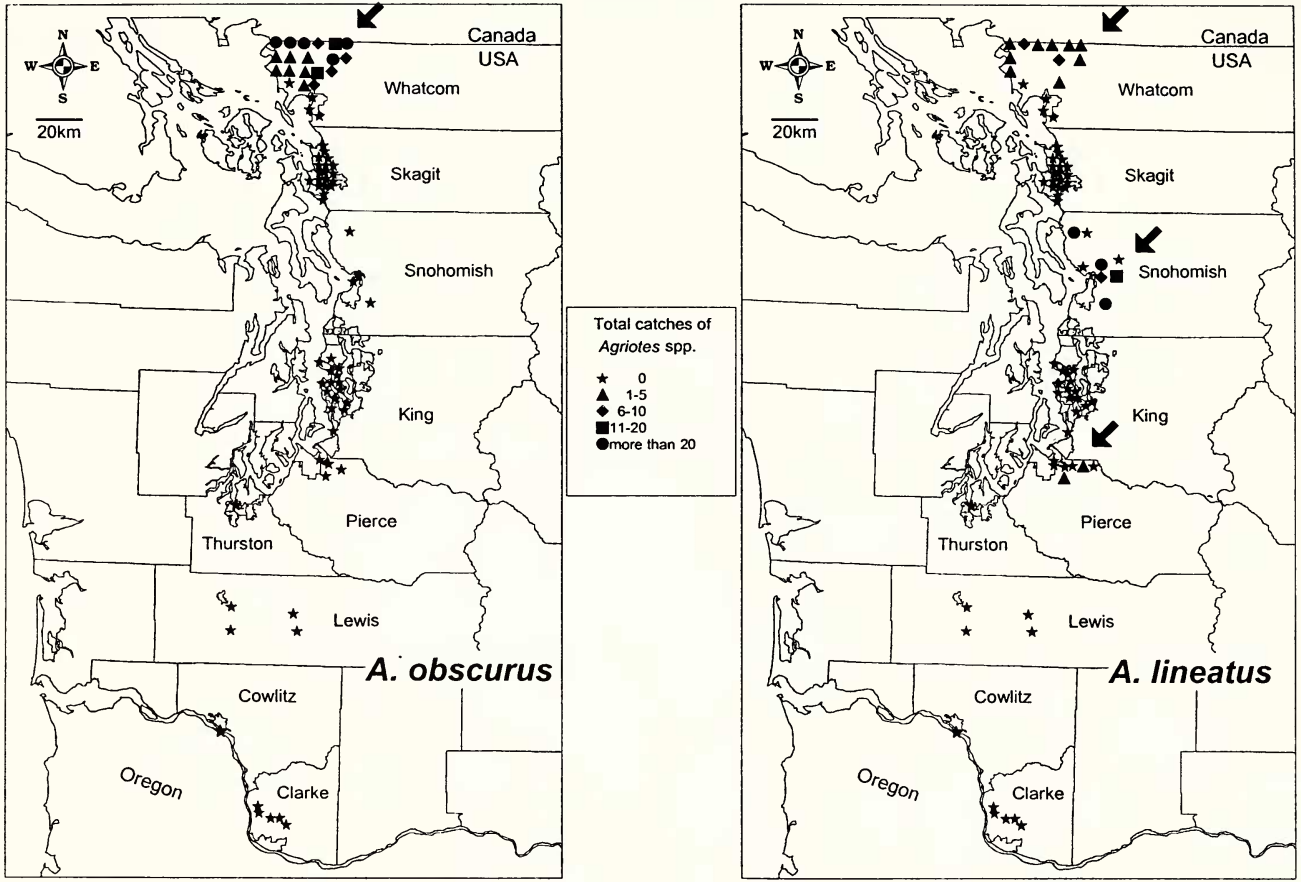

Figure 2. Locations of pheromone traps and total catch of *A. obscurus* and *A. lineatus* in nine counties in western Washington in 2000. Arrows indicate general areas where beetles were trapped.

Interior BC surveys. From 19-26 May, 2000, six pairs of *A. obscurus* and *A. lineatus* traps were established in the Similkameen Valley of BC between Keremeos and Osoyoos. From 26 May to 23 June, 29 pairs of traps were established in the Okanagan Valley between Osoyoos and Salmon Arm, and 13 pairs of traps between Salmon Arm and Kamloops from 23 June to10 July. An additional eight traps were established between Merritt and Kamloops in the Nichola Valley from 23-30 June. The traps were placed amongst grass in roadside ditches along highways and country roads. Paired traps were placed either on the same side of the road, and spaced 7-10 m apart, or placed on opposite sides of the road, and spaced 15-20 m apart.

Washington State surveys. Traps were initially installed from mid-April to early-May, 2000, and were checked as frequently as possible until removal in July or early August. Trap checking intervals varied from weekly in priority areas of Whatcom county, to a month or more in southwestern Washington counties. At sites where high levels of the target beetles were collected in the first trap checks in Whatcom County, traps were subsequently relocated to more southern locations to gather additional delimiting information. Trapping sites in the northern counties of Whatcom and Skagit were established in an approximate grid pattern, with between 3.2 and 6.4 km between traps (Fig. 2).

The physical criteria for trap sites included: proximity to areas of turf, pasture, or other grassy locations, which are considered favored wireworm habitat; and protected situations where traps would be less likely disturbed or damaged. Outside of the northern counties, traps were located near ports or nurseries where the target species may have been introduced through shipping ballast or infested nursery stock.

RESULTS

Initial and peak emergence of *A. obscurus* and *A. lineatus*.

Fields of strawberries that were monitored simultaneously for *A. obscurus* and *A. lineatus* in the Surrey region of the lower Fraser Valley in 2000 suggested that the peak activity period of adult *A. obscurus* males preceded that of *A. lineatus*. Unfortunately, numbers of *A. obscurus* taken in pheromone traps in the Surrey fields (installed 13 April) were already high when traps were first inspected on 19 April (range: 1.1-8.5 beetles per trap per day), indicating that the initial emergence period of *A. obscurus* had been missed. For *A. obscurus*, the highest recorded catches in traps occurred between 19-27 April in the Surrey fields (range: 1.6-8.5 beetles per trap per day), and between 19 April and 4 May in the Aldergrove, Abbotsford and Chilliwack fields (range: 1.3-20.8 beetles per trap per day). Numbers of *A. lineatus* in the Surrey fields were quite low in traps on 19 April (range: 0-0.11 beetles per trap per day) with peak catches occurring on 16 June (range: 0.9-1.9 beetles per trap per day). Trapping for *A. lineatus* began too late in the Aldergrove, Abbotsford and Chilliwack fields to determine the initial or peak activity periods.

Since it appeared that the initial emergence period of *A. obscurus* and *A. lineatus* was missed in 2000, sampling began between 14-22 March in the 2001 strawberry field surveys. Dates of first catch of *A. obscurus* varied considerably between the various regions monitored in the lower Fraser Valley in 2001 (Table 1). The very earliest catch of *A. obscurus* occurred on 23 March in five out of eight fields in Chilliwack at the eastern end of the lower Fraser Valley (mean of eight fields = 28 March) with mean initial catch in other regions ranging from 3-28 April. Mean peak catch of *A. obscurus* ranged from 3-19 May (Table 1). The dates of initial catch of *A. obscurus* are similar to those reported in Europe (i.e. United Kingdom, France, Switzerland and Poland), where initial captures generally occurred in the last week of March or first week of April (Cohen 1942).

The very earliest catch of *A. lineatus* in pheromone traps was again in Chilliwack in two

out of six fields on 17 April (mean of six fields = 24 April) with mean initial catch in other regions ranging from 24 April to 5 May (Table 1). Mean peak catch of *A. lineatus* among regions ranged from 25 May to 2 June (Table 1). The difference in mean initial and mean peak catch between *A. obscurus* and *A. lineatus* in the lower Fraser Valley was 15.6 and 18.7 days, respectively.

Table 1

Mean number of Julian days required for initial and peak catches of *A. obscurus* and *A. lineatus* in strawberry fields monitored with pheromone traps in eight regions of the lower Fraser Valley in 2001. Regions are arranged from east to west.

		Julian date of initial catch			Julian date of peak catch	
Region Monitored	# Fields[1]	*A. obscurus*	*A. lineatus*	# Fields[1]	*A. obscurus*	*A. lineatus*
Chilliwack	8:6	86.5	113.7	8:8	129.3	145.0
Sumas Prairie	5:5	105.8	117.6	5:4	122.8	148.0
Deroche	4:4	104.8	119.0	4:4	132.5	150.0
Abbotsford	4:4	110.0	122.0	0:4	-	150.0
S. Aldergrove	7:7	106.0	119.1	7:7	125.0	153.3
N.Aldergrove	8:8	93.0	119.5	8:8	131.5	149.0
Surrey	5:5	107.6	119.6	5:5	131.6	149.0
Delta	6:6	117.8	125.0	7:7	139.1	147.0
Mean		103.9	119.5		130.2	148.9

[1]The number of fields in each region with mean *A. obscurus* catch $\geq$ 0.1 (left number) or *A. lineatus* catch $\geq$ 0.1(right number) beetles per trap per day, during initial or peak trap catch.

Geographic distribution of *A. obscurus* and *A. lineatus*.

Lower Fraser Valley. In the initial pheromone trap survey of 17 strawberry fields in 2000, *A. obscurus* and *A. lineatus* were both found in all fields sampled in Richmond (one field), Delta (two fields), Surrey (four fields), Aldergrove (two fields) Abbotsford (two fields) and Chilliwack (six fields) (Fig. 1). Of 18 headland areas surrounding potato fields monitored with pheromone traps in Delta in 2000, both species were found in all but one field (i.e. on Westham Island) which failed to capture any *A. obscurus*.

The 2000 survey findings were verified and expanded upon in the survey of 50 strawberry fields in 2001, where both species were taken in pheromone traps in all fields monitored in Delta (8 fields), Surrey (5 fields), Aldergrove (16 fields), Abbotsford (4 fields), Mission/Deroche (4 fields), Sumas Prairie (5 fields) and Chilliwack (8 fields) (Fig. 1). Both species were also taken in pheromone traps placed in a fallow field in Agassiz. The catches of *A. obscurus* in Richmond and Mission/Deroche, and catches of *A. lineatus* in Aldergrove, Abbotsford, Mission/Deroche, Sumas Prairie, Chilliwack and Agassiz are the first records of these species in these areas, and both species now appear to coexist throughout the lower Fraser Valley.

The mean number and relative proportions of *A. obscurus* and *A. lineatus* in traps in geographically distinct groups of fields varied somewhat throughout the lower Fraser Valley in 2001 (Fig. 1). The data show that numbers of *A. obscurus* caught in pheromone traps were generally lower relative to *A. lineatus* in the western half of the Valley, but were higher in most of the sampled areas in the eastern half of the Valley. In the field sampled in Agassiz (north east of Chilliwack) in 2001, the proportion of *A. obscurus* was very high (0.98).

Okanagan Valley, BC. No specimens of *A. obscurus* or *A. lineatus* were taken in pheromone traps at any of the 56 sites sampled in the Okanagan, Similkameen or Nichola Valleys of BC between 19 May and 10 July in 2000. However, based on the observations

above which showed that *A. obscurus* emerges and peaks earlier than *A. lineatus* (Table 1), the traps that were set in the Nichola Valley from Merritt to Kamloops between 23-30 June, and those set between Kamloops and Salmon Arm between 30 June and 10 July, may have missed the *A. obscurus* and possibly the *A. lineatus* adult generations. The negative results in traps set in the Okanagan and Similkameen valleys, however, suggests that neither species has been introduced to those regions.

Merritt, BC. A single specimen of *A. lineatus* was found in the collection of Professor J.H. Borden (Simon Fraser University), which was caught between 1990-93 in a bark beetle pheromone trap at Miner Creek in an actively logged and reforested area 25 km southwest of Merritt (collector, Alejandro Camacho-Vera). This is the first record of *A. lineatus* in the interior of BC outside of the lower Fraser Valley.

Washington State. Of the eight counties monitored in 2000, *A. obscurus* was collected only in Whatcom county, where 18 out of 22 sites were positive and catches were highest near the Canadian border (Fig. 2). At these sites, between 68 and 76 adult *A. obscurus* were captured during 7-day trapping intervals in late April. *Agriotes lineatus* had a broader distribution, being captured in Whatcom (11 of 15 sites), Snohomish (5 of 8 sites) and Pierce (2 of 7 sites) counties. The highest average number of beetles per positive trap was in Snohomish county (21.2 beetles), followed by Whatcom county (2.5 beetles) and Pierce county (1 beetle).

The disparate collections of *A. lineatus* in this survey, occurring in three counties separated by counties without collections, suggest the possibility of a disjunct population of that species in parts of the Puget Sound area. The extent of collections that were recorded in this survey, occurring as far south as the Fife area in Pierce County, clearly demonstrates that *A. lineatus* is currently established in areas outside of the previously known infested areas of BC. Whether the detected populations in Snohomish and Pierce Counties represent natural spread from BC or are the result of independent introductions was not determined from this survey.

DISCUSSION

Since their hypothesized introductions to Vancouver Island (*A. obscurus* and *A. lineatus*) and Agassiz (*A. obscurus*) about a century ago (Wilkinson 1963), both species are now found throughout the lower Fraser Valley of BC, and at least *A. lineatus* is probably established near Merritt in the interior. Both species are also well established in areas of Washington state. The fact that *A. lineatus* was not found in pitfall traps at most sites east of Delta BC in the survey by Vernon and Päts (1997) shows the value of using pheromone traps as a delimiting survey tool for these species. Pheromone traps indicated that both species were present in virtually all fields monitored throughout the lower Fraser Valley, and the large numbers of beetles caught in some fields (e.g. 60 traps placed in one Chilliwack field in 2000 caught over 25,000 *A. obscurus*) indicates that both species are very well established. Because both species are polyphagous, and will feed among the roots of many crops, it is almost a certainty that they are being introduced to new areas through the movement of soil or via the transplanting of plants from infested areas. *Agriotes* spp. (either *A. lineatus* or *A. obscurus*) wireworms were found in soil surrounding cedar seedlings originating from the Chilliwack area that were awaiting planting at a Harrison Lake park (just north of Agassiz), and were also found in topsoil moved from a Chilliwack farm to a residence in Rosedale in 1996 (R.S. Vernon, personal observation). The abundance of *A. lineatus* and *A. obscurus* in the lower Fraser Valley and Washington state, and the distant movement of soil or plants with soil (i.e. ornamentals or seedlings for reforestation) will likely spread these pests rapidly to new regions of BC, Washington and beyond.

The observation that the time of emergence and peak catch of *A. obscurus* preceded that of *A. lineatus* by 15.6 and 18.7 days, respectively, will help to better streamline surveys and interpret data in the future. These observations are also important in the development of pest management strategies that target the adult stage of these species.

ACKNOWLEDGEMENTS

We thank Elaine Goudie, Anita Behringer, Bill Hedges, Patrick Hertzog, Harold Kamping, Jon Mullen, and ES Cropconsult Ltd. for setting and inspecting the pheromone traps, and Todd Kabaluk for figure preparation. This project was funded in Canada through collaborative research agreements between the Fraser Valley Strawberry Growers Association, the BC strawberry processors, Investment Agriculture Foundation, the Lower Mainland Horticultural Improvement Assn., PheroTech, Inc. and the Potato Industry Development Committee with matching funds from the Matching Investment Initiative of AAFC, and in the US by a 2000 Cooperative Agricultural Pest Survey grant from the USDA APHIS Western Region.

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